

Utah State University

DigitalCommons@USU

UAES Bulletins

Agricultural Experiment Station

6-1955

Bulletin No. 377 - Performance Testing Studies with Beef Cattle

James A. Bennett

Doyle J. Matthews

Follow this and additional works at: https://digitalcommons.usu.edu/uaes_bulletins



Part of the [Agricultural Science Commons](#)

Recommended Citation

Bennett, James A. and Matthews, Doyle J., "Bulletin No. 377 - Performance Testing Studies with Beef Cattle" (1955). *UAES Bulletins*. Paper 340.

https://digitalcommons.usu.edu/uaes_bulletins/340

This Full Issue is brought to you for free and open access by the Agricultural Experiment Station at DigitalCommons@USU. It has been accepted for inclusion in UAES Bulletins by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.



1281

PERFORMANCE TESTING STUDIES WITH BEEF CATTLE

James A. Bennett and Doyle J. Matthews

AGRICULTURAL EXPERIMENT STATION
UTAH STATE AGRICULTURAL COLLEGE

no. 377
Performance Testing Studies with
Beef Cattle.



Summary

PERFORMANCE tests were conducted over a four year period with 124 beef calves that were fed for 168 days. The data were analyzed by a method of covariance analysis for unequal subclass numbers.

● Significant differences were found between sire offspring groups for rate of gain and final feedlot weight and highly significant differences for efficiency of feed utilization.

● The influence of sex was pronounced. Bull calves, during the 168-day feeding period, gained 0.66 pounds more per day, gained 4.63 pounds more for each 100 pounds of total digestible nutrients consumed, and were 113.34 pounds heavier at the end of the feeding period, than heifer calves, when proper adjustments were made for other factors.

● Weight of the calf at the start of the feeding test did not significantly influence rate of gain but it had a highly significant influence on efficiency of gain and final feedlot weight when proper adjustments were made for the other factors studied.

● Age of dam did not significantly influence rate of gain, efficiency of gain, or final weight when adjustments were made for sire, sex, and initial weight.

● The value of four measurements taken on live steers as a means of estimating dressing percentage and thus, indirectly, percent fat in the live animal was determined with 144 steers. Live weight, heart girth, and paunch girth show a highly significant correlation with dressing percent, and height at withers a significant correlation. These four measurements gave a highly significant multiple correlation. The coefficient of determination was low, however, and indicated that these measurements would not give a highly reliable estimate of dressing percentage or, indirectly, of percent fat in the live steer. However, the method appears to be worthy of further study.

	<i>Page</i>
INTRODUCTION	5
REVIEW OF LITERATURE	5
METHODS AND PROCEDURE	7
Record of performance tests	7
Value of body measurements as a basis for estimating dressing percentage	8
Weights	8
Body measurements	8
RESULTS AND DISCUSSION	9
Performance testing	9
Rate of gain	10
Efficiency of gain	10
Final weight	11
Estimation of dressing percentage	12
LITERATURE CITED	15

The authors:

James A. Bennett is professor and head of the Department of Animal Husbandry; Doyle J. Matthews is assistant professor of animal husbandry.

This study was conducted in cooperation with the Animal and Poultry Husbandry Research Branch, Agricultural Research Service, United States Department of Agriculture and the state agricultural experiment stations under Western Regional Project W-1 on beef cattle improvement.

Acknowledgements:

Sincere appreciation is expressed to Professor Bliss H. Crandall for his advisory assistance in carrying out the statistical analysis and to the following graduate students: James T. M. Shen, Lloyd G. Transtrum, and Earl S. Allred for their assistance in collecting and processing the data.

THE GOAL in beef cattle breeding is the production of animals that make rapid and efficient gains and have desirable conformation. Performance testing has recently been advanced as a means of identifying individuals possessing superior productive qualities and as a means of evaluating sires for transmitting these

qualities to their offspring. This report gives the results of performance tests conducted with Hereford and Shorthorn calves fed over a constant time period as well as the results of a supplemental study undertaken to gain information that might add refinement to the evaluation of gains in beef cattle.

Review of Literature

CATTLE BREEDERS have, in the past, relied largely on selection based on the appearance of animals to maintain and improve productive qualities. Numerous experimental workers have shown, however, that there are wide differences in rate and efficiency of gain among steers of the same type and market grade (Rice 1934, Winters and McMahon 1933, Winters 1936, Rice 1942, and Clark *et al.* 1944).

Means, other than the appearance of the animal, have been suggested for evaluating beef sires. Holbert (1932) proposed a procedure based on show ring winnings. Winters and McMahon (1933) presented a system based on daily gain to one year of age and a score based on slaughter grade. Black and Knapp (1936) proposed a system in which rate and efficiency of gain are measured in a feeding period over a weight range of 500 to 900 pounds.

Knapp *et al.* (1942) reported that a feeding period of 168 days was suitable for determining differences in sire progeny groups, provided the data were adjusted for differences in initial weight. They concluded, also, that the first 8 progeny of a sire were

sufficient to give an indication of his ability to transmit efficiency of feed utilization. Stanley and McCall (1945) concluded that 8 offspring should be minimum and that 10 or 12 would be more desirable.

Knapp and Baker (1943) found that full feeding was more effective for measuring differences among calves than was limited feeding.

Differences among animals in the ability to utilize feed efficiently are difficult to measure accurately. Rate of gain is, apparently, related to some extent to efficiency (Winters and McMahon 1933, Black and Knapp 1938, Roubicek *et al.* 1951). Kleiber (1936) concluded that absolute rate of gain could be used as an index to efficiency only when animals are of the same size. Similarly, Guilbert and Gregory (1944) found that absolute rate of gain was not a satisfactory index of economy of gain in groups differing in potential mature size and earliness of maturity. The relative rate of gain and relative feed capacity (gain and feed capacity per unit of metabolic body size) were highly related to efficiency of feed utilization. Knapp and Baker (1944) also concluded that comparisons of gross efficiency should only be

made between animals of the same size.

It is known that superior performance for many of the characteristics that can be measured in performance tests with cattle are transmitted to a high degree. In recently revised heritability estimates, as obtained by half-sib correlations, Knapp and Clark (1950) gave the following percentage values: "Birth weight 53; weaning weight 28; final feedlot weight at 15 months 86; gain on feed 65; weaning score 28; slaughter steer grade 45; carcass grade 33; and area of eye muscle 68 percent. Estimates based on sire offspring regression for final weight at 15 months were 92 percent and for rate of gain in the feedlot were 77 percent."

Bogart and Blackwell (1950) concluded that a bull or cow which gains rapidly and efficiently will generally produce offspring that gain rapidly and efficiently, also. This again indicates a high level of heritability for these characteristics.

Sex has been observed to influence rate of gain. Koger and Knox (1945) found that steer calves were 32 pounds heavier than heifer calves, on the average, at weaning time. Gramlich and Thalman (1930) reported that, following weaning, steer calves gained 0.15 pounds more per day than did heifer calves. They found further that steer calves required 42 pounds of shelled corn and 23 pounds of alfalfa less than did the heifers for each 100 pounds of gain.

Bogart and Blackwell (1950) found that bulls gained faster and more efficiently than did heifers. In this test bulls gained an average of 2.34 pounds each per day while heifers gained 1.74 pounds. The bulls required 791 pounds of feed per 100

pounds of gain in weight and the heifers required 1,056 pounds for the same amount of gain.

The efficiency with which an animal gains is materially affected by the composition of the gains. Branaman *et al.* (1936) found that there was an increase of 8.26 percent in terms of net energy required per 100 pounds of gain accompanying an increase in fatness in beef steers. Brody (1945) points out that two steers may gain weight at different rates, yet gain energy at the same rate. This is possible because some types of gains involve greater energy storage per unit of live weight. Brody (1945:753) states that, "Moreover, the energy equivalent of one gram fat is $2\frac{1}{4}$ times that one gram protein. Hence, one gram fat gain is calorically equivalent to about eight grams protein gain (including the associated water)."

Inherent differences in animals, that are manifested in different rates of fat deposition in relation to weight gains, would, therefore, have a pronounced effect on the amount of feed required per unit gain.

The determination of the percentage fat in the entire body of an animal or in the carcass by either chemical or physical means is laborious and expensive. Lush (1936) devised a method whereby fat content could be rather accurately estimated without making a direct determination. He reported that the percentage fat content of the body of a live steer could be estimated from the dressing percentage. The correlation between dressing percentage and percentage fat in the entire body was found to be 0.84 in his study. The estimating equation was as follows:

$$\text{Percentage fat in live animal} = 1.782 (\text{dressing percentage}) - 86.4$$

In the performance testing of future breeding animals it is requisite that differences in composition of gains in weight be determined on live animals. There is a definite possibility that measurements, taken on the live animal, may be useful for this purpose. Brody (1927) pointed out that height at withers is but slightly influenced by environmental conditions; while the girth of chest or paunch tends to be influenced by various degrees of nutrition to the same relative extent as growth in weight. Lush (1928) found that height at withers was not greatly affected by changes in condition and that chest girth was the most useful

single measurement that increased with increasing fatness. Similarly, Black *et al.* (1938) found height at withers to be an excellent skeletal measurement and that heart girth increased steadily with increased condition.

These results indicate that as an animal increases in condition, heart girth, paunch girth, and weight increase while height of withers tends to be more constant. This suggests that differences in condition and in dressing percentage might be estimated with reasonable accuracy through comparing height of withers with these other measurements.

Methods and Procedure

Record of Performance Tests

PERFORMANCE tests involving individual feeding were carried out with 124 calves produced in the Utah Agricultural Experiment Station's Hereford and Shorthorn herds at Logan, Utah. All the living offspring in these herds, except a few that were culled because of obvious defects, through the years 1948 to 1952 were subjected to a performance test. These animals were the offspring of 6 Hereford and 3 Shorthorn sires. The cows were assigned largely at random within breed to the sires with the exception that intense inbreeding was generally avoided.

The plan of handling the calves was uniform throughout the four-year period. Throughout the summer the young calves and their dams grazed on irrigated pastures. No creep feeding was practiced. The calves were

weaned at approximately 7 months of age and placed in a dry lot where they were fed alfalfa hay and a small amount of grain. They were accustomed to being handled and tied up during the seventh to eighth month. On the Saturday morning nearest to the time when the calf would be 8 months old the animal was weighed and the performance test was started. The test consisted of full feeding for a 168-day period. Weights were taken in the morning before feeding or watering at four-week intervals during the first two years and at weekly intervals during the last two years.

Calves were fed twice daily at approximately 6:00 a.m. and 5:00 p.m. The concentrate mixture was fed first then hay was given after the animal had finished eating the concentrates. Both hay and concentrates were weighed to the animal and any feeds left over in the manger were weighed

back. Wheat or barley straw was used for bedding. Clean water was available in a trough in each yard. Good quality alfalfa hay was the only roughage provided. The concentrate mixture was as follows:

	Parts by weight
Coarsely ground barley	60
Coarsely ground wheat	15
Dried molasses beet pulp	20
Linseed oilmeal	5
Salt	1
Steamed bonemeal	1

The ratio of concentrates to roughages was varied during the 168-day feeding time as follows:

Period	Hay parts	Concentrate mixture parts
1st 28 day	1.00	1.00
2nd 28 day	1.00	1.50
3rd 28 day	1.00	2.00
4th 28 day	1.00	2.50
5th 28 day	1.00	2.75
6th 28 day	1.00	3.00

All calves were full fed, according to appetite, within the limits of the concentrate: roughage ratios specified above throughout the trial.

Calf weights were read at the nearest pound and feed weights to the nearest one-tenth of a pound. Efficiency of feed utilization was calculated as the number of pounds gained per 100 pounds of total digestible nutrients consumed.

The data were analyzed by a method of covariance analysis for multiple classification tables with unequal subclass numbers described by Hazel (1946).

Value of Body Measurements as a Basis for Estimating Dressing Percentage

The animals used in this study were 144 beef steers of Hereford, Short-horn, and Angus breeding which were fed and shown by members of 4-H and Future Farmers of America organizations from the Intermountain Area. These animals were shown at the Intermountain Junior Livestock Show at the North Salt Lake Stockyards. Live weights of these steers ranged from 600 to 1203 pounds and slaughter grades ranged from commercial to prime.

Weights

The live weights used were the official weights accepted. These were determined in the following manner:

The official weight was the off-truck weight at the North Salt Lake Stockyards for animals trucked over 100 miles. For animals trucked less than 25 miles, 25 to 50 miles, or 51 to 100 miles, the official weight was 97 percent, 98 percent, and 99 percent of the off-truck weight, respectively.

Body Measurements

Calipers and a steel tape, both graduated in centimeters, were used to measure the animals. For measuring, each animal was placed in a level standing position with all four legs placed as squarely as possible. The head was held in a normal position.

Height of withers was measured with a vertical caliper and was the distance from the top of the withers to the floor directly in line with the foreleg.

Heart girth was measured with a steel tape at the point of smallest circumference directly behind the forelegs. The tape was pulled snugly about the animal, tight enough to hold down the hair but not tight enough to indent the flesh.

Paunch girth was measured with a steel tape at the point of largest circumference just anterior to the sheath.

The tape was pulled snugly as in the case of the heart girth measurement.

Dressing percentage was determined through the use of the accepted official live weight and the warm carcass weight less 3 percent shrink.

The data were analyzed for correlation and regressions according to methods described by Snedecor (1948) and Wallace and Snedecor (1931).

Results and Discussion

Performance Testing

AVERAGE unadjusted values for the various characteristics measured during the performance testing are presented in table 1. The offspring of all sires were combined in making these calculations. Bull calves were

found to be heavier than heifer calves. They also gained faster and more efficiently and were heavier at the end of the 168-day feeding test. Considerable variation existed among both bulls and heifers in all characteristics studied.

The results of detailed statistical

Table 1 Averages for several characteristics of beef test calves

Sex	Number	Initial weight	Age of dam	Daily gain	Efficiency* of gain	Final weight
		<i>pounds</i>	<i>years</i>	<i>pounds</i>	<i>pounds</i>	<i>pounds</i>
Bulls	64	455	5	2.27	22.60	836
Heifers	60	399	5	1.61	19.46	670

*Efficiency is expressed as the number of pounds of gain for each 100 pounds of total digestible nutrients consumed.

Table 2 Analysis of variance of rate of gain

Source	Degrees of freedom	Mean squares	F values
Sires	8	0.2097	2.47*
Sex, adjusted for all other effects	1	9.8169	115.7653**
Age of dam, adjusted for all other effects	1	0.1239	1.4610
Initial weight, adjusted for all other effects	1	0.0084	0.0990
Error	112	0.0848	

*Significant at the 0.05 level

**Significant at the 0.01 level

analyses by the least squares method for disproportionate numbers (Hazel, 1946) for rate of gain, efficiency of gain, and final weight are given in tables 2 and 3, 4 and 5, and 6 and 7, respectively.

Rate of Gain

As shown in table 2, the sire influence was significant and the sex

Table 3 Estimated values for daily rate of gain for several variables

Variable	Daily rate of gain	
	<i>pounds</i>	
Sire* 1	2.15	
Sire 2	2.17	
Sire 3	2.30	
Sire 4	2.40	
Sire 5	2.15	
Sire 6	2.61	
Sire 7	2.17	
Sire 8	2.29	
Sire 9	2.42	
Male sex	0.66	more than for female
Age of dam	0.01	increase for each year advance in age
Initial weight	0.0002	increase for each pound increase in initial weight

*Average rate of gain for offspring of each sire adjusted to 455 pound initial weight, 5-year old dam, and male sex basis

Table 4 Analysis of variance of efficiency of gain

Source	Degrees of freedom	Mean squares	F values
Sires	8	25.714	5.11**
Sex, adjusted for all other effects	1	4854.107	963.69**
Age of dam, adjusted for all other effects	1	10.745	2.13
Initial weight, adjusted for all other effects	1	200.623	39.8298**
Error	112	5.037	

**Significant at the 0.01 level

influence highly significant for rate of gain but the age of dam and the weight of calves at the start of the feeding trial did not significantly affect rate of gain when the proper adjustments were made for the other characteristics.

The sex influence upon rate of gain was striking. Bull calves gained 0.66 pounds more per day than did heifer calves (table 3). These results agree rather closely with those reported by Bogart and Blackwell (1950). It would seem, therefore, that data collected with heifer calves could properly be used, with adjustment, along with data from bull calves in evaluating beef sires for transmitting gaining ability.

Efficiency of Gain

The results of the analysis of variance for efficiency of gains (table 4) were somewhat similar to those for rate of gain in that the sire and sex influence were significant. One exception, however, occurred. Initial weight had a highly significant effect upon efficiency.

The sex influence was pronounced. Male calves, as shown in table 5, gained 4.63 pounds more for each 100

pounds of total digestible nutrients consumed than did heifer calves. The cause for this difference in efficiency is not readily apparent from the data. There is a possibility that the gains of the heifer calves were composed of

more fat and less bone, water, and lean tissue than were the gains of the bulls. However, no detailed measures of percent fat in the bodies of the live animals of either sex were made and no exact cause was determined.

Table 5 Estimated values for efficiency* of gain for several variables

Variable	Efficiency of gain
	<i>pounds</i>
Sire† 1	19.6
Sire 2	22.4
Sire 3	23.1
Sire 4	22.6
Sire 5	23.7
Sire 6	27.4
Sire 7	20.7
Sire 8	22.3
Sire 9	23.0
Male sex	4.63 more than for female
Age of dam	0.11 increase for each year advance in age
Initial weight	0.02 decrease for each pound increase in ini- tial weight

*Efficiency is expressed as the number of pounds of gain for each 100 pounds of total digestible nutrients consumed.

†Average efficiency of gain for offspring of each sire adjusted to 455 pound initial weight, 5-year-old dam, and male sex basis.

Initial weight showed a negative regression on efficiency of gain. Each pound increase in initial weight was accompanied by a decrease of 0.02 pounds gain for each 100 pounds of total digestible nutrients consumed when adjustments were made for the other factors (table 5). This emphasizes that weight of the animal must be considered when describing efficiency. If proper comparisons of efficiency are to be made, they should be made among animals of the same weight or else statistical adjustments of the measured efficiency are required.

Final Weight

The analysis of variance of the final weight taken at the end of the 168-day feeding period (table 6) showed a significant sire influence and highly significant sex and initial weight influence.

The regression value for the male sex, as shown in table 7, shows that

Table 6 Analysis of variance of final weight

Source	Degrees of freedom	Mean squares	F. values
Sires	8	6947.8183	2.16*
Sex, adjusted for all other effects	1	291423.5322	90.5116**
Age of dam, adjusted for all other effects	1	3582.1948	1.1125
Initial weight, adjusted for all other effects	1	349214.7372	108.4607**
Error	112	3219.735	

*Significant at the 0.05 level

**Significant at the 0.01 level

Table 7 Estimated values for final feedlot weight for several variables

Final feedlot	
Variable	weight pounds
Sire* 1	815
Sire 2	813
Sire 3	831
Sire 4	864
Sire 5	812
Sire 6	890
Sire 7	818
Sire 8	837
Sire 9	861
Male sex	
	113.34 more than for female
Age of dam	
	1.99 increase for each year advance in age
Initial weight	
	0.91 increase for each pound increase in initial weight

*Average final weight for offspring of each sire adjusted to 455 pound initial weight, 5-year-old dam, and male sex basis.

the male calves were, approximately, 113 pounds heavier than the female calves at the conclusion of the feeding test when adjustments were made for the other factors.

Initial weight has an influence on final weight. The results (table 7) indicated that animals that are heavier at the start of the test are heavier at the end and they will be almost as much heavier at the end as they were at the start if proper adjustments are made for sire and sex. This point is worthy of consideration in selecting individuals from among test animals. Animals that are fully penalized for being small at the start of the test should not be penalized again at the end of the test for being small because of the close relation between the weight at the start and at the end of the test period.

The combined results of the analyses of variance indicate that when

the performance of individual animals or progeny groups of animals are to be compared on the basis of a time constant feeding test some adjustments in the test results are needed. In evaluating rate of gain, adjustment for sex is worthwhile. A further adjustment for initial weight is desirable in measuring efficiency and in evaluating weight at the end of the feeding test.

Estimation of Dressing Percentage

This supplemental study was conducted for the purpose of determining if body measurements would provide a means to evaluate more accurately gains in weight in cattle and thus provide a more precise measure of efficiency of feed utilization. As pointed out by Brody (1945) the composition of the gains determines the amount of energy that is stored with each unit of increase in weight. Since heart girth, paunch girth, and weight are influenced markedly by level of nutrition while height of withers, heart girth, and paunch girth pears that these combined measurements might be useful for estimating percent fat in live animals. An estimate of their value for measuring percent fat could be obtained by finding their relation to dressing percentage since Lush (1926) demonstrated that dressing percentage was highly correlated to percent fat in a live animal.

Results of testing the relation of the four body measurements of beef steers viz. live weight, height at withers, heart girth, and paunch girth to dressing percentage are shown in table 8. The multiple correlation coefficient of .4757 is highly significant but the coefficient of determination is low and indicates that these four

body measurements account for only 22.63 percent of the variability in dressing percentage. These measurements would, therefore, not supply accurate predictions of dressing percentage and thus would be limited in their usefulness for indirectly estimating percentage fat in the body of a live beef animal.

Some interesting relations exist among these measurements. Dressing percentage is affected to a greater extent by the heart girth measurements than by any of the other single measurements studied. As indicated by the regression coefficients, the height at withers, live weight, and paunch girth gave little additional in-

formation when used in conjunction with the heart girth measurement. However, each of the four regression coefficients is statistically significant and is worth including in a prediction equation.

The simple correlation coefficients for several body measurements and dressing percentage are shown in table 9. The value of .4123 for heart girth and dressing percentage is nearly as large as the multiple correlation value found for the four measurements (table 8). However, including the other three measurements does increase the accuracy of predictions.

The simple correlation coefficients for height at withers, live weight, and

Table 8 The multiple regression of the dressing percent on the live weight, height at withers, heart girth, and paunch girth measurements of 144 beef steers weighing 600 to 1203 pounds

	Live weight	Height at withers	Heart girth	Paunch girth
	<i>pounds</i>	<i>centimeters</i>	<i>centimeters</i>	<i>centimeters</i>
Regression coefficients	-.002895*	-.115545*	.265821*	-.080081*
Regression equation	Dressing percent = 44.07912 - .002895 (weight) - .115545 (height) + .265821 (heart girth) - .080081 (paunch girth)			
Multiple correlation	= .4757*		Coefficient of determination = 22.63 percent	

*Significant at the 1 percent level of probability.

Table 9 Correlation coefficients showing the relation between various live body measurements and the dressing percent of 144 beef steers weighing 600 to 1203 pounds

Measurements and ratios	Dressing percent
Live weight3231
Height at withers2107
Heart girth4123
Paunch girth2656
Height at withers ÷ heart girth	-.3479
Height at withers ÷ live weight	-.2374

.174 is significant at the 5 percent level of probability

.228 is significant at the 1 percent level of probability

paunch girth on dressing percentage indicate that dressing percentage increases slightly with an increase in these measurements. The negative regression coefficients for these measurements when considered individually in the multiple regression analysis (table 8), indicate that although there is a slight increase in dressing percentage with increases in height, weight, and paunch girth, when considering the group as a whole, each of the three measurements has a negative effect on dressing percentage when it is possible to hold the effects of the other measurements constant. In other words, an increase in paunch girth, for example, would be accompanied by a decrease in dressing percentage if height of withers, heart girth, and weight remained constant.

The ratio of height of withers to heart girth gave a highly significant correlation coefficient with dressing percentage. This should be expected if height of withers is, to a large degree, a skeletal measurement and heart girth measurement an indicator of condition as reported by Brody (1927) and Black *et al.* (1938) and since, as Lush (1926) pointed out, dressing percentage is significantly related to percentage fat. In this analysis, however, the ratio of height

of withers to heart girth does not account for enough of the variability to be highly valuable in estimating dressing percentage.

This study indicates that, although there are significant relations between all the body measurements taken on the live steers and dressing percentage, estimating dressing percentage by means of these measurements would not be highly accurate. The multiple correlation obtained by including all four measurements is highly significant but the coefficient of determination is sufficiently low that much of the variation is unaccounted for by these measurements. It is apparent, therefore, that these measurements would not be highly useful for estimating dressing percentage and thus indirectly percentage fat in live steers on an individual basis.

The relations are sufficiently high to be encouraging, however, and it appears that they are worthy of further study. In this study some variations in amount of fill were, no doubt, influencing weight. If a means had been devised for obtaining a uniform amount of fill in each animal and thus a more exact weight, the body measurements would, undoubtedly, have predicted dressing percentage with greater accuracy.

LITERATURE CITED

- Black, W. H., and B. Knapp, Jr. A method of measuring performance in beef cattle. *Amer. Soc. Anim. Prod. Proc.* 1936: 72-78.
- Black, W. H. and B. Knapp, Jr. A comparison of several methods of measuring performance in beef cattle. *Amer. Soc. Anim. Prod. Proc.* 1938: 103-107
- Black, W. H., B. Knapp, Jr., and A. C. Cook. Correlation of body measurements of slaughter steers with rate and efficiency of gain and with certain carcass characteristics. *Jour. Agr. Res.* 56: 465-472. 1938.
- Bogart, Ralph, and R. L. Blackwell. More beef with less feed. *Ore. Agr. Exp. Sta. Bul.* 488. 1950.
- Branaman, G. A., O. G. Hankins, and L. M. Alexander. The relation of degree of finish in cattle to production and meat flavors. *Amer. Soc. Anim. Prod. Proc.* 1936: 295-300. 1936
- Brody, Samuel. The relation between weight growth with special reference to dairy cattle. *Mo. Agr. Exp. Sta. Res. bul.* 103. 1927. p. 40.
- Brody, Samuel. Bioenergetics and growth. New York, Reinhold Pub. Co., 1945. p. 1033.
- Clark, R. T., B. Knapp, Jr., A. L. Baker, and J. R. Quesenberry. Performance-testing of beef cattle. *Mont. Agr. Exp. Sta. Bul.* 417. 1944.
- Gramlich, H. J., and R. R. Thalman. Sex and age as factors in cattle feeding. *Neb. Agr. Exp. Sta. Bul.* 252. 1930.
- Guilbert, H. R., and P. W. Gregory. Feed utilization tests with cattle. *Jour. Anim. Sci.* 3: 143-153. 1944.
- Hazel, L. N. The covariance analysis of multiple classification tables with unequal subclass numbers. *Biometrics bul.* 2: 21-25. 1946.
- Holbert, J. C. Show ring winnings as a means of evaluating sires. *Amer. Soc. Anim. Prod. Proc.* 1932: 52.
- Klieber, M. Problems involved in breeding for efficiency of food utilization. *Amer. Soc. Anim. Prod. Proc.* 1936: 247-258.
- Knapp, Bradford, Jr. Determination of slaughter steer grades from weights and measurements. *U. S. Dept. Agr. Cir.* 524. 1939.
- Knapp, Bradford, Jr., R. W. Phillips, W. H. Black, and R. T. Clark. Length of feeding period and number of animals required to measure economy of gain in progeny tests of beef bulls. *Jour. Anim. Sci.* 1: 285-292. 1942.
- Knapp, Bradford, Jr., and A. L. Baker. Limited vs. full-feeding in record of performance tests in beef cattle. *Jour. Anim. Sci.* 2: 321-327. 1943.
- Knapp, Bradford, Jr., and A. L. Baker. Correlations between rate and efficiency of gain in steers. *Jour. Anim. Sci.* 3: 219-223. 1944.
- Knapp, Bradford, Jr., and R. T. Clark. Revised estimates of heritability of economic characteristics in beef cattle. *Jour. Anim. Sci.* 9: 582-587. 1950.
- Koger, M., and J. H. Knox. Effect of sex on weaning weight of range calves. *Jour. Anim. Sci.* 4: 15-19. 1945.
- Lush, J. L. Practical methods of estimating the proportion of fat and bone in cattle slaughtered in commercial packing plants. *Jour. Agr. Res.* 32: 727-755. 1926.
- Lush, J. L. Changes in body measurements of steers during intensive fattening. *Tex. Agr. Exp. Sta. Bul.* 385. 1928.
- Rice, V. A. Breeding and improvement of farm animals. 2d ed. New York, McGraw-Hill Book Co., 1934. p. 516.
- Rice, V. A. Breeding and management of farm animals. 3d ed. McGraw-Hill Book Co., 1942. p. 745.
- Roubicek, C. B., N. W. Hilston, and S. S. Wheeler. Progeny studies with Hereford and Shorthorn cattle. *Wyo. Agr. Exp. Sta. Bul.* 307. 1951.
- Stanley, E. B., and R. McCall. A study of performance in Hereford cattle. *Ariz. Agr. Exp. Sta. Tech. bul.* 109. 1945. p. 53
- Winters, L. M., and H. McMahon. Efficiency variations in steers. *Minn. Agr. Exp. Sta. Tech. bul.* 94. 1933. p. 28.
- Winters, L. M. Studies of breeding for increased efficiency. *Amer. Soc. Anim. Prod. Proc.* 1936: 263-265